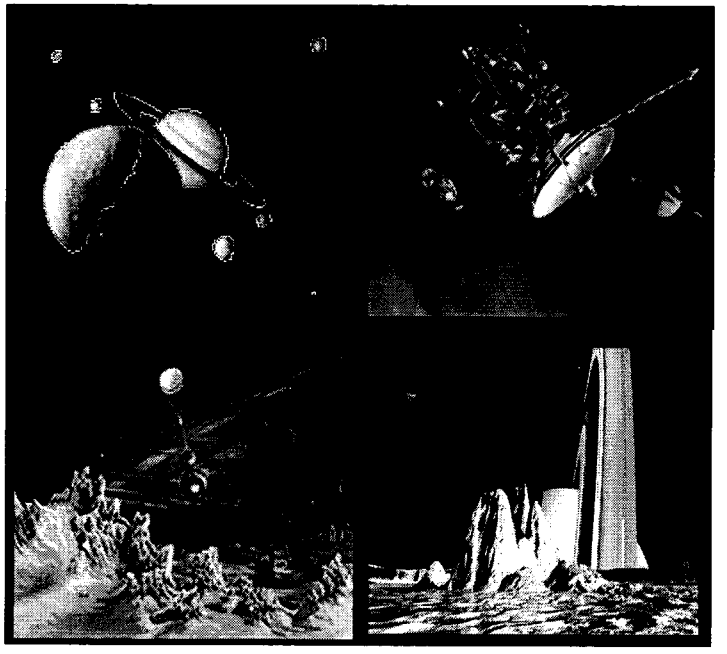
Cassini Science Planning Process



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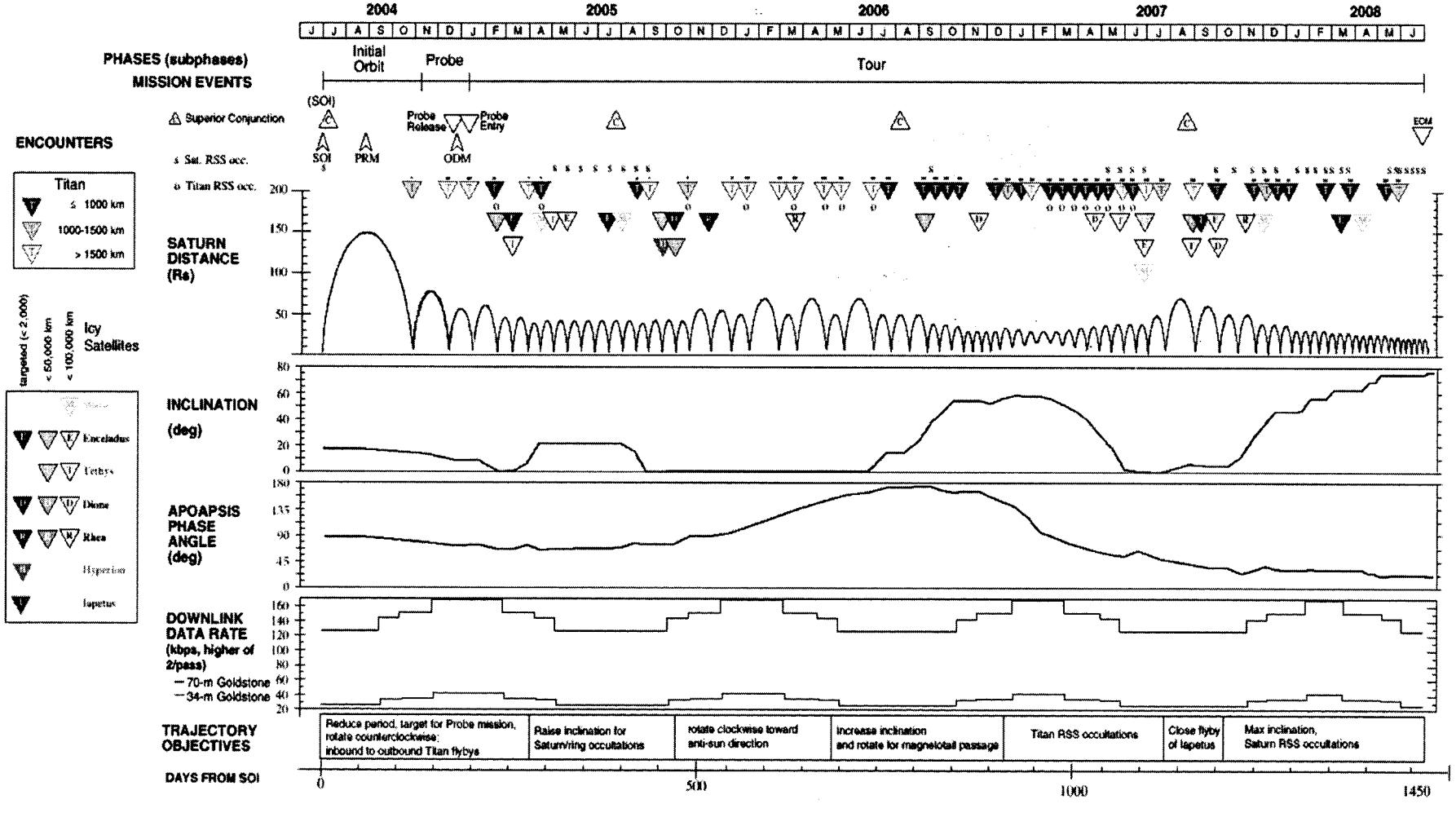
Mission Overview

- **Combined Saturn orbiter and Titan atmospheric probe (Huygens)**
  - Three-axis stabilized spacecraft (reaction wheels and thrusters)
  - 27 science investigations from 12 orbiter, 6 Huygens instruments
  - Once fixed high-gain antenna, two low-gain antennas
  - Three RTGs for power
  - Redundant main engines, attitude thrusters (8)
  - Two Solid-State Recorder of 2.0 Gbits each
- **Launched 15 October 1997 on Titan IV/Centaur into 6.7-year Venus-Venus-Earth-Jupiter trajectory to arrive on 1 July 2004**
- **4 year Prime Mission**
  - 75 orbits
  - 44 targeted Titan flybys
  - 9 targeted icy satellite flybys
  - 41 sequence loads

Tour Overview



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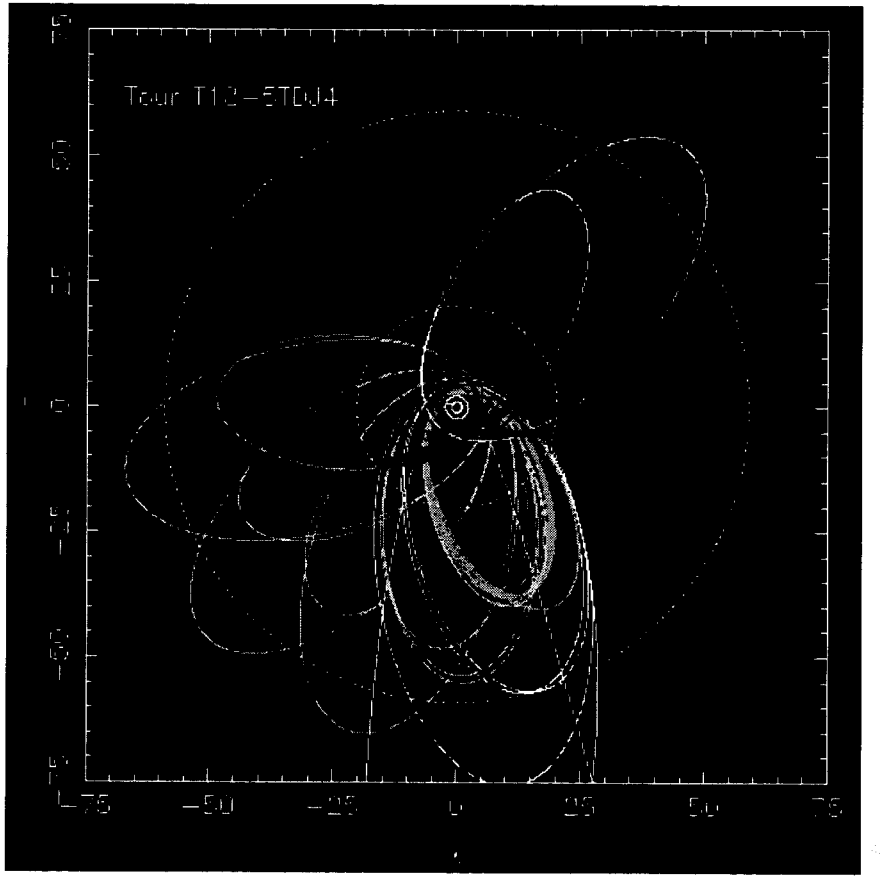
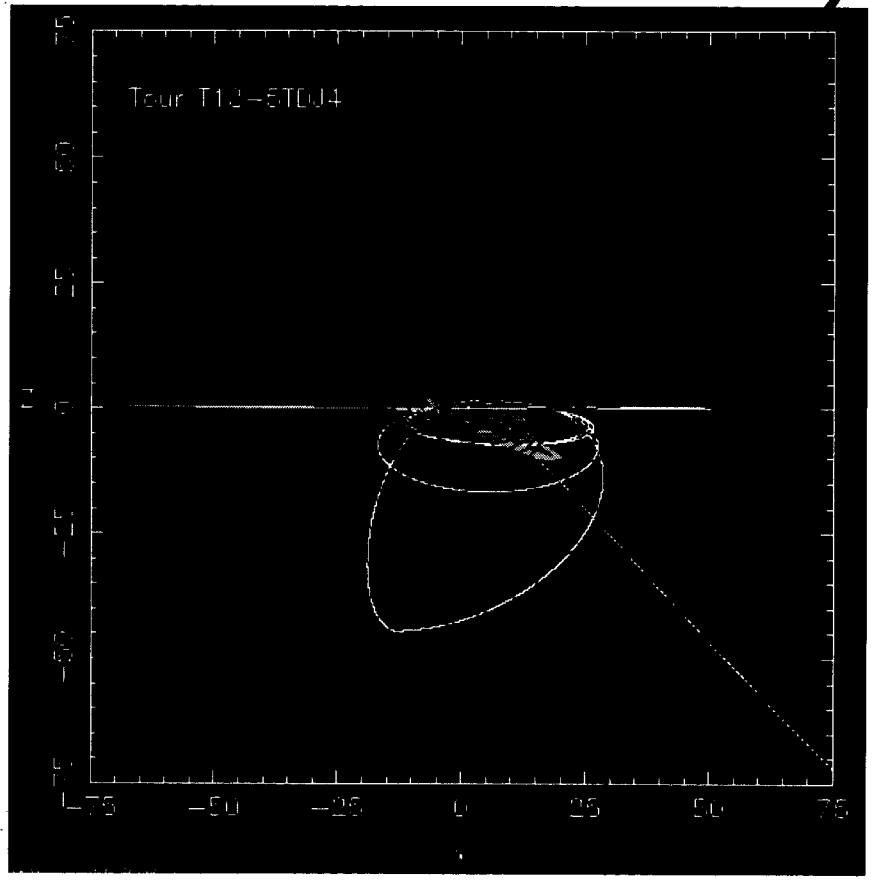
Tour Overview (Cont'd)



North Pole View



Side View

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Mission Comparison

	CHARACTERISTIC	VOYAGER	GALILEO	CASSINI
MISSION	Orbits	6 (flybys)	11	75
	Average Orbit Duration	120 days (flyby)	8 weeks (5 wks - 8 wks)	3 weeks (1 wk - 3months)
	Operations Environment	Centralized	Centralized	Distributed
	Prime Mission Duration	2 years	2 years	4 years
	Total Mission Data Volume	~4,000 Gbits	2 Gbits	~3,000 Gbits
SPACECRAFT	Scan Platform	Yes	Yes	No
	Maximum Turn/Slew Rates	1°/sec	1°/sec	0.4°/sec-RCS 0.2°/sec-RW
	Power Modes	1	8	12
	Recorder Volume	.5 Gbits	.9 Gbits	4 Gbits
	Imaging Instruments	2	2	8
	Science Instruments	11	12 Orbiter 6 Probe	12 Orbiter 6 Probe
UPLINK PLANNING	Science Plan Development Time	9:1	5:1	3:1
	Sequence Loads/Orbit (Average)	10 loads/flyby	3 (1 encounter, 2 orbital cruise)	4-5 weeks (n orbits/load)
	Targets & Periapses/Load (Average)	10 loads/flyby	1periapse, 1satellite	2 periapse, 2 satellites
	Sequence Load Size	2.5 Kwords	16 Kwords	150 Kwords
	Science Operations Staff (JPL)	~60	60	23
	Investigation Team Size	~150	187	254

Science Planning Challenges

- **Distributed Operations**
  - Remoteness & Timezones
  - Mismatch between spacecraft design and operations environment
- **Lack of Scan Platform**
  - Instrument pointing constraints
  - Downlink/observation time-sharing
- **Simultaneous Ops**
  - Long-Term/Short-Term Science Planning Development
  - Sequence development and execution
- **FSW/GSW development**
  - Timeliness of software development
- **Complexity of Spacecraft Operations**
  - Pointing constraints
  - Power modes
  - Telemetry modes
- **Tour Selection**
  - Discipline focused groups
- **PSG ownership of process**
- **Funding & Schedule Drivers**

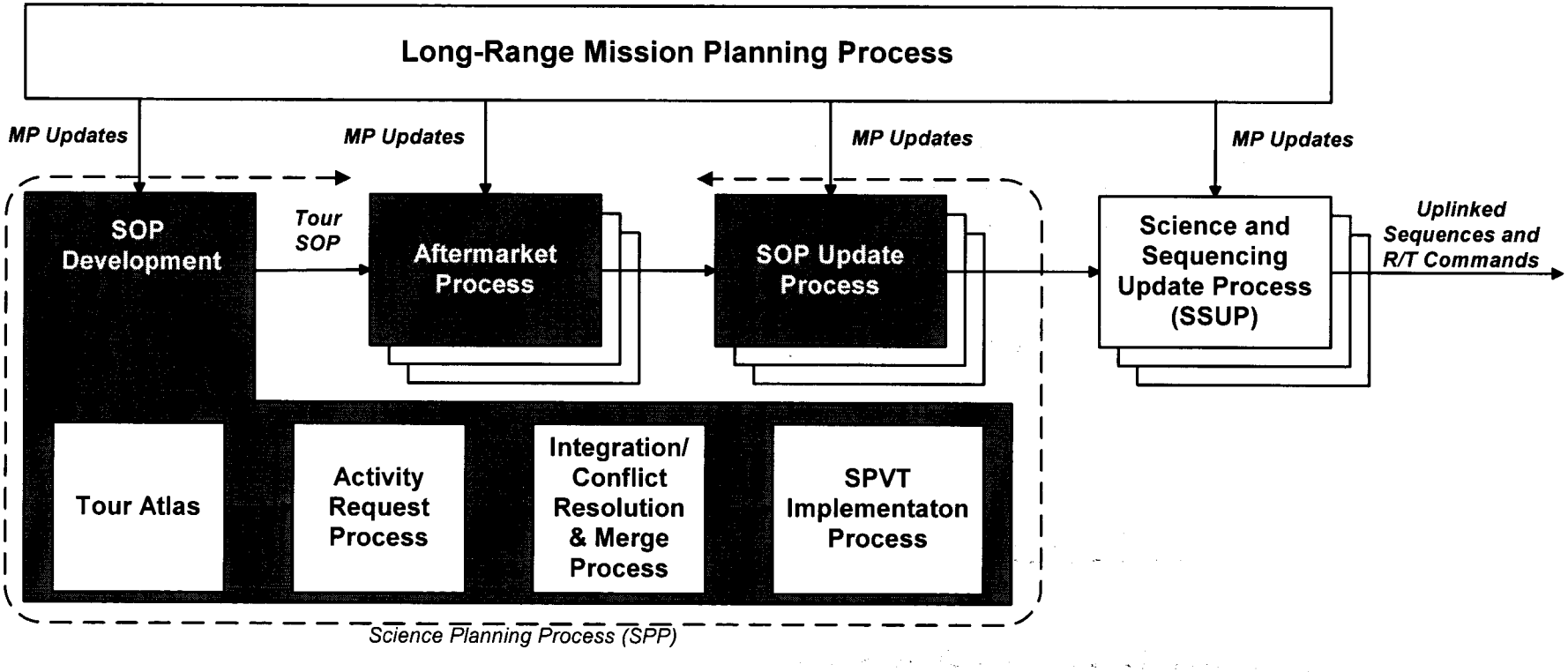
Science Planning Timeline

When	What (goals)	Who	Details
10 years before Prime Mission	**Tour Design** (maximize science opportunity)	Science Community, Mission Planning (some Spacecraft)	Science experiment trade-offs, navigation and uplink development capabilities.
4 years before PM	**Integration** (negotiate best science compromise)	Science Planning, Science Community (some Spacecraft, some Mission Planning)	Break up entire mission by science discipline and negotiate shared resources (pointing, power, telemetry, and data volume), lack of a scan platform makes this a challenge.
2 years before PM	**Implementation** (validate basic sequence design)	Science Planning, Science Operations Spacecraft Team (some Mission Planning)	3 chances to get a skeleton sequence of the shared resources in place and validated, distributed operations makes this a challenge.
20 weeks before execution	**Adaptation** (update integrated plan)	Science Planning, Science Community (some Spacecraft, some Mission Planning)	Update integrated plan based on new discoveries, science data analysis, spacecraft/instrument performance changes, etc.
15 weeks before execution	**Implementation Update** (update basic sequence design)	Science Planning, Science Operations Spacecraft Team, (some Mission Planning)	1 chance to update the skeleton sequence to any updated science compromises and/or new discoveries.
10 weeks before execution	**Sequencing** (validate entire sequence)	Sequence Lead, Science Operations, Spacecraft Team (some Science Planning)	2 cycles to create a complete sequence, all commands in place and validated, complexity of spacecraft and plans make this a challenge.

Science Planning Process Selection

- **Integration**
  - Option 1
    - Small science-savvy group at JPL responsible for the integration of the Tour.
      - Cons: Not scientifically optimized; huge workload on small group; politics of empowerment
      - Pros: Rapid integration; problem solution inheritance
  - Option 2
    - Large single PSG group that integrates the entire Tour except the target flyby.
      - Cons: Large membership makes for slow process; large group dynamics issues
      - Pros: Distribute workload amongst all PSG members; problem solution inheritance; science community representation;
  - Option 3
    - Smaller PSG groups with responsibilities split up by science discipline and/or target body.
      - Cons: Better communication/coordination between integration groups; some members needed to support multiple groups
      - Pros: 4 parallel efforts increases workforce utilization; discipline/target body focused group; PSG co-leadership of group (empowerment); optimized science plan
- **Implementation**
  - Significant inheritance from Galileo Science Planning Operations Process

Science Planning Process Schedule/Flow



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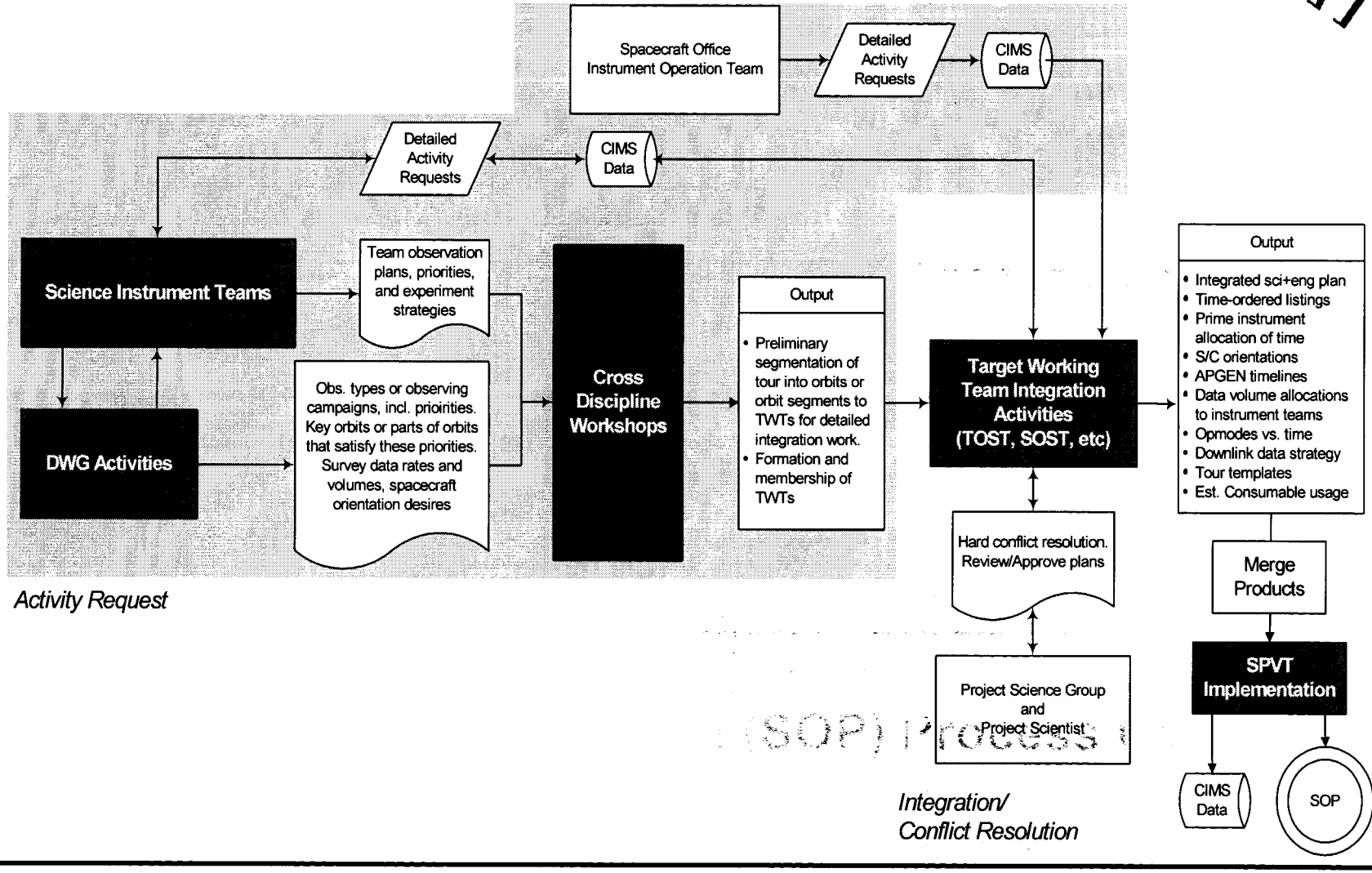
Science Operations Plan (SOP) Process Overview



Science Planning Process Current Status

- **SOP Integration**
  - Approach Science: 100% complete on May 2003.
  - Tour Science: 100% complete on January 2004.
- **SOP Implementation**
  - Approach Science: 100% complete and 2 of 3 sequences have executed on board the spacecraft.
  - Tour Science : A total of 68% (28 out of 41) of the Tour sequences "complete" and "on-the-shelf".
- **Aftermarket (Integration Update)**
  - Updated the plans for 3 of 41 sequences.
- **SOP Update**
  - Completed 3 of 41 sequences.

Lessons Learned

- **Better use of concurrent engineering practices related to development & operations**
  - Consideration of operability factored into spacecraft development
- **Distributed operations is not the low cost operations option**
  - Redundant hardware and software infrastructure
  - Training and cross-training
- **Exercising the systems as early as possible prior to prime mission**
  - Jupiter Flyby
  - Verification and Validation (V&V) System Testing
- **Effective communication**
  - Web-based interactions
- **Centralized web-based database critical**